BRIDGE DAMAGE AND RECONSTRUCTION FROM TOHOKU REGION PACIFIC COAST EARTHQUAKE

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Abstract

In March 11, 2011, Tohoku Region Pacific Coast Earthquake was generated with magnitude 9.0, the hypocenter located off Sanriku at 130km ESE of Oshika Peninsula. It was the strongest ever recorded in Japan and the fourth largest in the world. Furthermore, this great earthquake created tsunami waves of up to 40.5m high. In this paper, the damage that we observed by on-site inspection and the reconstruction are described for the bridge that had been designed by us.

1. EARTHQUAKE SUMMARY

The main shock of Tohoku Region Pacific Coast Earthquake occured at 2:46pm on March 11, 2011. The Hypocenter located off Sanriku at 130km ESE of Oshika Peninsula with the focal depth of 24km, as shown in figure 1. It was Magunitude 9.0, and ocean-trench-type earthquake on the subduction zone plate boundary between the Pacific and the North America plates (Near the Japan trench). The magunitude of this earthquake was the largest in the history of seismic observation in Japan, and surpasses M. 7.9 of Kanto earthquake (The Great Kanto Earthquake) in 1923 and M. 8.4 of Showa Sanriku earthquake in 1933. Moreover, this earthquake caused the tsunami waves, which arrived not only Japan but also some countries of the pacific region, were up to 40.5m high (Miyako-shi, Iwate) that exceeded the record of the one of Sanriku earthquake in 1896. Additionally, this earthquake created many disasters such as landslides, ground liquefaction, and land subsidence, all of which harmed the lifelines over the wide area. According to the U. S. Geologial Survey, it was the fourth largest earthquake in the world since 1900. The 7.1 magunitude aftershock occured off the coast of Miyagi on April 7.

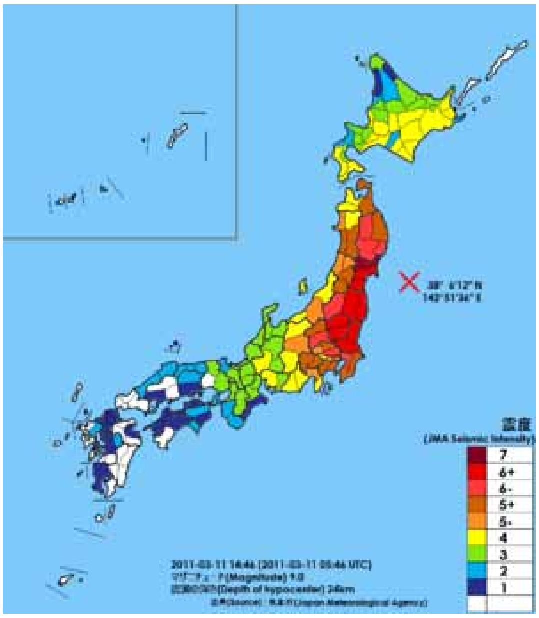

Figure 1: Hypocenter

The earthquake and tsunami caused great damage to the road network that was important for reconstruction activity. Many bridges were also damaged, and the secondary disasters (e.g. delay in delivering relief supplies) were observed.

2. BRIDGES DAMAGE AND RECOVERY METHODS

2.1 Damage by the Tsunami

The tsunami is the most remarkable disaster during the Tohoku region Pacific coast earthquake. Generally, bridge is affected by seismic force due to an earthquake motion. However, in the Tohoku earthsquake, many bridges damaged by not only the seismic force but also the transverce force due to the tsunami and the upward force due to the buoyancy. In this section, the bridge damages by the tsunami are reported.

(1) Omoto Bridge

The bridge was subjected to the tsunami waves directly, as shown in photo 1. And the waves crashed on the dam downstream and splashed. The superstructure did not fall down due to decreasing of the tsunami wave energy. However the railing was extremely distorted outward, as shown in photo 2.

(2) Numata Bridge over railway

The bridge was consisted of the several post-tension simple T-beams. All superstructure fell down by the tsunami wave, as shown in photo 3. The superstructure was attached to the substructure with the anchor bars, as shown in figure 2. Because the anchor bars were found to be still straight after the disaster, it is considered that the superstructure was moved up by the buoyancy and then was washed away by the flowing water pressure.

Photo 1 : Tsunami waves

Photo 2 : Railing damage

Photo 3 : Numata bridge

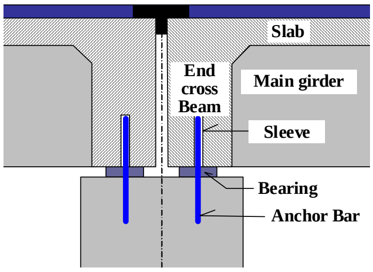

Figure 2: Joint structure

2.2 Damage by the Earthquake and Recovery Method

In this section, Fuji Bridge and Koyagi Bridge with severe damages are reported. Those bridges had no enormous damage at the main shock, but were severely damaged by the aftershock.

Figure 3 shows the response acceleration spectrum which were using the seismic wave recorded near two bridges. The response acceleration spectrum of the main-shock is high in the short-period range. While, in the cose of the aftershock, the peak is at 0.8 seconds which is similar to the natural period of two bridges. It is considered as the cause of the damages of two bridges.

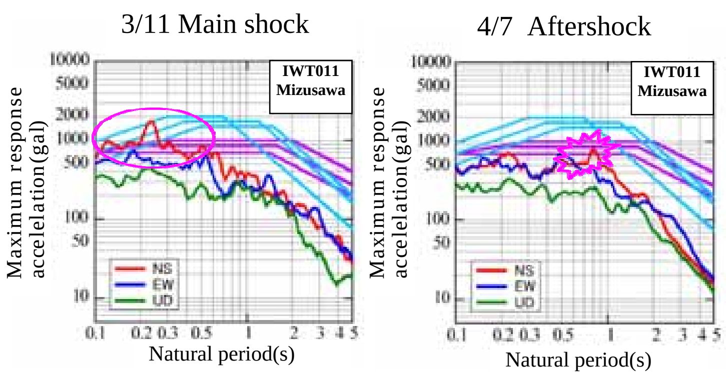

Figure 3: Response acceleration spectrum

(1) Fuji Bridge

Fuji Bridge is shown in photo 4. The pin bearings were broken by the aftershock and the pins dropped as shown in photo 5. In the piers of this bridge, a tensile yeild of the longitudinal reinforcement and the compression failure of concrete were observed at the upper part of the section where the amount of reinforcement was changed, as shown in photo 6 and 7.

Photo 4 : Fuji Bridge

Photo 5 : Bearing failure

Photo 6 : Pier damage

Photo 7 : Flexural failure

To obtain the emergency transportation, a temporary repair work was carried out for the bearing. The time efficiency is important in reconstruction. Therefore, the method using shaped steel was adopted as shown in photo 8.

In the reconstruction of the piers, to aviod the damaged portion from slip by possible aftershocks, the method of restraining the H-section steels around the piers by the wire was adopted. Situation and detail of the reconstruction were shown in the photo 9 and figure 4 respectively.

Photo 8 : Temporary repair work for bearing

Photo 9 : Reconstruction situation

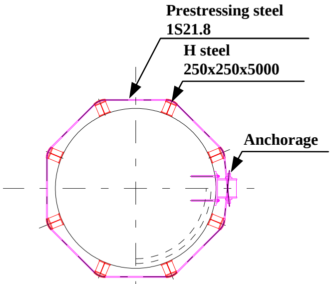

Figure 4 : Reconstruction detail

(2) Koyagi Bridge

Koyagi Bridge is shown in photo 10. Since the top slab of the bridge foundation with open-caisson sagged and tilted, the column of the bridge tilted to the downstream side as shown in Photo11 and figure 5. The deformation of the railing as shown in photo 12 was caused by the displacement of foundation.

To confirm the possibility that the displacement progresses by the various factors including the traffic load and the possible aftershocks, the cause of the foundation displacement (e.g. top slab sagging) was investigated prior to reconstruction. As a result of the investigation, some voids under the top slab, passing-through cracks of the top slab, and 1 meter scouring were found. Since the result showed there was a possibility that the further displacement occurs, reconstruction was carried out as shown in figure 6.

Photo 10 : Koyagi Bridge

Photo 11 : Caisson damage

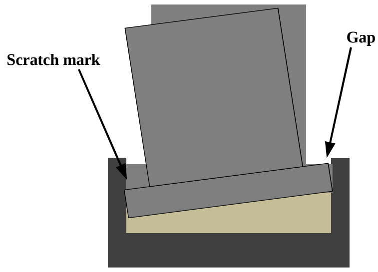

Figure 5 : Damage situation

Photo 12 : Railing damage

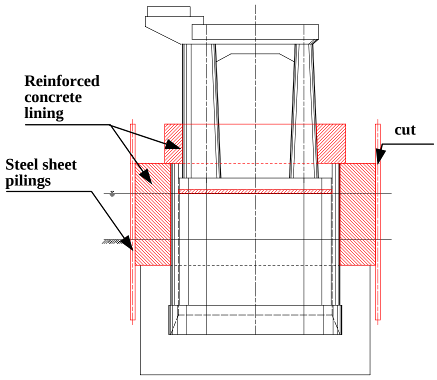

Figure 6 : Reconstruction of Caisson

3. CONCLUSIONS

This paper describes the damages and the reconstruction method for the bridges which had been designed by us and undergone the earthquake and the tsunami. The following observations and conclusions are made on the research reported in this paper and our on-site inspection.

1. The notisable damage during Tohoku region Pacific coast earthquake was that many bridges washed away by the tsunami.
2. The cause of a part of the bridge washed away is presumed that the beams was moved up by the buoyancy.
3. Many of the damaged bridges were not applied antiseismic reinforcement and were designed and constructed based on the specifications for highway bridges before 1996.
4. Depending on the characteristic of the earthquake motion, some bridges were damaged not by the main shock but by the aftershock.
5. It is necessary to conduct a systematic antiseismic reinforcement, because few seismic reinforced bridges were damaged during Tohoku region Pacific coast earthquake.